International Orthopaedics (SICOT) (2002) 26:306–309
DOI 10.1007/s00264-002-0360-6

ORIGINAL PAPER

Eric Vandenbussche · Louis-Denis Duranthon
Monique Couturier · Louis Pidhorz
Bernard Augereau

The effect of tourniquet use in total knee arthroplasty

Accepted: 2 April 2002 / Published online: 2 August 2002

Abstract We conducted a prospective, randomised study on primary total knee replacements to evaluate the effects of tourniquet use on total calculated blood loss using Gross formula, post-operative measured blood loss, operating time, need for blood transfusion, post-operative pain, analgesia requirement and knee flexion. Forty patients were operated on with the use of an arterial tourniquet with pressure of 350 mmHg (group A), and 40 patients without the use of a tourniquet (group B). Total calculated blood loss was significantly increased (P=0.0165) without the use of a tourniquet. There was no significant difference in measured blood loss or operating time. The median units of blood given were similar in both groups. In spite of autologous transfusions 14% of patients received additional homologous transfusions. At 6 h post-operatively pain was significantly less (P=0.0458) in group B but was similar at 24 and 48 h. There was no significant difference in analgesia requirement. The mean change in total flexion in group B was significantly better (P<0.001) at 5 days than in group A, but knee flexion was similar at 10 days and 3 months. Knee arthroplasty operations without the use of a tourniquet cause a greater blood loss but have only small benefits in the early post-operative period.

Written in conjunction with the Groupe d'Utilisation et d'Etude des Prothèses Articulaires (GUEPAR), Paris, France

E. Vandenbussche (✉) · L.-D. Duranthon · B. Augereau
Department of Orthopaedic Surgery, Hôpital Européen Georges Pompidou, 20 Rue Louis Blanc, 75908 Paris Cedex 15, France
e-mail: eric.vdb@egp.ap-hop-paris.fr
Tel.: +33-1-56-093280, Fax: +33-1-56-092395

M. Couturier
Department of Anesthesiology, Hôpital Européen Georges Pompidou, 20 Rue Louis Blanc, 75908 Paris Cedex 15, France

L. Pidhorz
Department of Orthopaedic Surgery,
Centre Hospitalier Universitaire d'Angers,
49033 Angers Cedex 01, France

Résumé Une étude prospective et randomisée a été réalisée sur 80 arthroplasties totales du genou consécutives de première intention dans le but d'évaluer l'effet de l'utilisation du garrot pneumatique sur les pertes sanguines totales calculées selon la formule de Gross, les pertes sanguines mesurées par drainage aspiratif, la durée opératoire, la nécessité de transfusion sanguine, la douleur post-opératoire, le besoin d'antalgique et la récupération de la flexion du genou. Quarante patients ont été opérés avec un garrot pneumatique gonflé à 350 mmg (group A), et quarante sans garrot pneumatique (group B). Les pertes sanguines totales calculées étaient plus élevées de façon significative (P=0.0165) dans le groupe B. Il n'y avait pas de différence significative entre les deux groupes sur les pertes sanguines mesurées par drainage aspiratif et la durée opératoire. Le nombre de culots globulaires nécessaire était le même dans les deux groupes. Malgré un protocole d'autotransfusion, 14% des patients ont eu une transfusion homologue complémentaire. La douleur post-opératoire était significativement moindre (P=0.0458) à la sixième heure dans le groupe B mais était identique à 24 et 48 heures. Il n'y avait pas de différence sur la consommation d'antalgique. La flexion dans le groupe B était meilleure (P<0.001) au cinquième jour que dans le groupe A, mais était identique à 10 jours et au troisième mois post-opératoire pour les deux groupes. La non-utilisation d'un garrot pneumatique apporte quelques bénéfices dans la période post-opératoire immédiate mais est responsable d'une majoration des pertes sanguines totales calculées.

Introduction

Despite progress in pre-operative autologous donation, intraoperative normovolaemic haemodilution and pre-operative acute normovolaemic haemodilution with erythroapheresis, many patients undergoing total knee arthroplasty (TKA) still require homologous transfusions. In 1984 Berman et al. [3] estimated that recording drain outputs was not adequate to allow quantification of overall blood loss. Post-operative blood loss may be considerable in ref-

erence to calculated blood loss [11], even if the use of a tourniquet allegedly minimises intraoperative blood loss.

Salam and Eyres [14] reported an increased incidence of post-operative pain, delay in recovery of muscle power, wound complications and deep-venous thrombosis (DVT) with the use of a tourniquet in patients undergoing TKA. Wakankar et al. [17], however, found no increase, except for range of knee flexion at 1 week.

We assessed the effects of using a tourniquet for primary TKA in a prospective randomised study with special reference to measured blood loss in suction drainage, total calculated blood loss, transfusion requirements, post-operative pain and knee flexion. To our knowledge it is the first such study on total calculated blood loss with or without tourniquet use.

Materials and methods

Eighty consecutive primary TKAs in 80 patients were performed between December 1997 and December 1999 in two orthopaedic centres. Patients with diabetes, haemostasis defect, rheumatoid arthritis, previous thromboembolism, abnormal vascular supply to the leg, previous open knee surgery and bilateral TKA were excluded. Forty-two patients had pre-operative autologous donation of blood (PAD). Just prior to the operation the patients were randomly divided into two groups using sealed envelopes. In group A (40 patients) TKA was performed with the use of a tourniquet, and in group B (40 patients) without. Neither the patients, physiotherapists nor nurses were informed as to whether or not a tourniquet was used.

The operations were all performed under general anaesthesia by a single surgeon or house staff using a standardised technique. Cefamandol 1500 mg was given intravenously at induction of anaesthesia, and four further doses of 750 mg were given post-operatively. Standard anticoagulant prophylaxis using enoxaparine was started the evening before surgery and continued until the patient was fully mobile.

In group A the limb was first exsanguinated by elevation for 2 min, then the tourniquet was inflated to 350 mmHg. If the duration of tourniquet use exceeded 90 min, the tourniquet was released intraoperatively and haemostasis was completed. After 10 min of release a new exsanguination was instituted. The tourniquet was not released until after the wound was closed and the compressive dressing applied.

In all patients a posterior cruciate ligament-retaining prosthesis was used (Wallaby I) (Protek-Sulzer, Bern, Switzerland). All components were cemented using palacos cement with gentamicin (Palacos-Genta, Schering-Plough). All drill holes in the distal femur were filled with an autogenous bone plug. Two 1-in. suction drains were inserted before closure. After closure the knee was placed in a compressive dressing after the application of a wool and crepe bandage to the limb. The knee was immobilised in extension. Post-operatively, all had patient-controlled analgesia (PCA) with an infusion of morphine sulphate. Active isometric quadriceps and continuous passive movement was begun on the second post-operative day, and walking with full weight bearing was permitted as tolerated under the supervision of a physical therapist.

The total operating time was recorded. Haemoglobin and haematocrit was recorded pre-operatively and at the first and tenth day post-operatively. Intraoperative blood loss in sponges was not recorded. Nurses using graduated cylinders recorded post-operative blood loss from the suction drains. Drains were removed when the drainage was recorded as less than 100 ml during a 12-h period. Overall blood loss was calculated as the sum of compensated and non-compensated blood loss. The latter was calculated as described by Gross [6]. The level of haemoglobin guided the need for transfusion. Generally, a patient received one or more blood units if the haemoglobin level was less than 9 g/dl (5.56 mmol/l).

A linear analogue scale assessed post-operative pain at 6, 24 and 48 h post-operatively, and from the patient's morphine requirements. We did not distinguish thigh pain from wound pain. The total quantity of opiate consummation in the first 24 and 48 h was recorded.

The time to achieve straight-leg raising and range of knee movement achieved at 5 days, 10 days and 3 months was documented by the physiotherapists. Wound complications, haematoma and confirmed thromboembolism by venography were also recorded. Radiographical analysis was conducted at 3 months looking for early signs of loosening, i.e. radiolucency at the bone-cement interface.

Statistical analysis

Data were analysed using analysis of variance, Student's *t*-test, Mann-Whitney *U* test, chi-square test and Pearson's correlation test, where appropriate. For all determinations a *P*-value of less than 0.05 was considered significant.

Results

Despite randomisation the two groups of patients were well matched: There were no significant differences in respect to age, gender, side, weight, diagnosis and pre-operative autologous donation (Table 1).

There was no significant difference in operating time. In group A average duration of tourniquet use was 123.5 (70–180) min. Seven patients had the tourniquet inflated once and 33 twice. No technical difficulties were encountered during surgery without tourniquet use. In particular, there were no difficulties in preparing the bone surfaces for cementing.

There were no significant differences in suction drainage blood loss and total number of blood units transfused. The calculated overall blood loss was significantly greater in patients in group B (P=0.0165) than patients in group A, with a difference of 322 ml (Table 2).

There was no significant correlation between operating time and total calculated blood loss in either group, no significant correlation between calculated blood loss and the suction drainage blood loss and no significant correlation between suction drainage blood loss and the need for transfusion.

Six of the 42 patients with PAD received one or two additional homologous blood units. In three cases this was because pre-operative donation was limited by medical problems; the other three cases were in spite of sufficient pre-operative donation. Among patients without PAD five out of 38 had no need for transfusion.

Pain scores at 6 h were significantly lower for patients in group B (P=0.0458). At 24 and 48 h there was, however, no significant difference in mean pain score. Mean post-operative morphine requirement did not differ the first 2 days post-operatively.

All patients achieved full extension of the knee. The range of active knee flexion measured at 5 days post-operatively was significantly greater (P<0.001) in patients

Table 1 Pre-operative patient characteristics

	Group A (*n*=40)	Group B (*n*=40)	*P*-value
Mean age (yr) (range)	72.5 (38–89)	68.5 (50–81)	NS (Student's *t*-test)
Gender – male:female	9:31	16:24	NS(analysis of variance)
Side – right:left	26:14	20:20	
Mean weight (kg) (range)	73.65 (52–110)	80.25 (50–110)	NS (Student's *t*-test)
Diagnosis			
Osteoarthritis	38	37	NS (chi-square test)
Osteonecrosis	2	3	NS (chi-square test)
Pre-operative autologous donation (PAD)			
No PAD	22:18	16:24	NS (analysis of variance)

Table 2 Operating time, post-operative measured blood loss in suction drainage, calculated overall blood loss, transfusion requirements

	Group A (*n*=40)	Group B (*n*=40)	*P*-value
Operating time (min) (range)	151 (100–240)	156.5 (120–240)	NS (Student's *t*-test)
Mean measured blood loss in suction drainage (ml) (range)	528.5 (90–2100)	661.6 (160–1,820)	NS (Student's *t*-test)
Mean calculated overall blood loss (ml) (range)	1234.9 (143–2,355)	1557.4 (323–2,896)	0.0165 (Student's *t*-test)
Mean total number of transfused BU (range)	2.0 (0– 5)	2.1 (0–5)	NS (Mann-Whitney *U*)
Autologous (range)	1 (0–3)	0.7 (0–3)	NS (Mann-Whitney *U*)
Homologous (range)	1.0 (0–3)	1.4 (0–4)	NS (Mann-Whitney *U*)
Non-transfused patients	4	1	NS (chi-square test)

Table 3 Post-operative complications

	Group A (*n*=40)	Group B (*n*=40)	*P*-value
Mean days in hospital (range)	11.2 (8–16)	11.8 (8–15)	NS (Student's *t*-test)
Nerve paralysis	0	0	NS (chi-square test)
Wound infection	0	0	NS (chi-square test)
Problem with wound healing	0	0	NS (chi-square test)
Haematoma	0	0	NS (chi-square test)
Deep-venous thrombosis	1	2	NS (chi-square test)
Radiolucency on femur, tibia or patella at 3 months	0	0	NS (chi-square test)

in group B; however, at 10 days and 3 months there was no significant difference. There was no need for manipulation under anaesthesia to improve knee flexion.

There were no significant differences in duration of hospitalisation. No patients had nerve paralysis, wound infection, difficulty with wound healing, haematoma or radiological evidence of radiolucency at 3 months. Tibial DVT was suspected and confirmed by venography in two patients in group A at 8 and 11 days after surgery, and in one patient in group B at 7 days after surgery (Table 3).

Discussion

In our study the measured suction drainage blood loss, which averaged about 600 ml, and the need for transfusion, were similar to previous reports [3, 4, 5, 9, 10, 11, 12, 13].Calculated total blood loss was similar to the values reported by Lotke et al. [11] who observed a mean of 1518 ml. Our principal finding was, however, that calculated total blood loss in the group without tourniquet was significantly higher. A possible explanation may be that the operating time in our study was longer than reported by other authors [2, 14]. A thorough haemostasis in the surgical approach was certainly a factor, which increased operating time. Another explanation may be a bias in the selection of patients, which, in a university centre, certainly differs from patients in private practice. Also, to detect possible malposition of the prosthetic components, we systematically used pre-operative radiography. All these factors may explain why our operating time was longer and different from routine clinical practice. We have not been able to reduce operating time below 90 min.

In our study measured suction drainage blood loss was not a good predictor of total blood loss. Our results contrast with those of Lotke et al. [11] who found a strong statistical correlation between these variables. A possible explanation may, again, be the longer operating time. However, we agree with Lotke et al. [11] that measured suction drainage blood loss represents approximately one third of the calculated total blood loss.

Our series showed that, despite autologous transfusions, 14% of patients were in need of additional homologous blood transfusions. The use of new techniques for decreasing homologous blood requirements in TKA, such as pre-operative acute normovolaemic haemodilution with erythroapheresis, and – in particular – a more accurate pre-operative estimation of total blood loss, might improve those results.

In patients for whom a tourniquet was not used, we found a significant reduction in post-operative pain and a better initial recovery of knee flexion, but only in the early post-operative period. This may be due to absence of local pressure or absence of local quadricipital rhabdomyolysis. Tourniquet pressure is a disparate factor that can affect the results of studies such as this. We used a pressure of 350 mmHg in this study; however, pressure may vary according to surgical staff. For example, studies using twice the patient's systolic blood pressure have been reported [2, 14, 17]. In such cases pressure is not uniform because it is governed by the individual's systolic blood pressure. Burkart et al. [4] used 300 mmHg and Stringer et al. [15] 500 mmHg. A pressure of 100 mmHg above systolic blood pressure is recommended by Worland et al. [18] to reduce thigh pain following tourniquet application.

Like Wakankar et al. [17], we found that complication rates associated with TKA were the same with or without use of a tourniquet. Harvey et al. [7] found the incidence of DVT was unrelated to tourniquet use, whereas others observed an increased incidence [14]. Recently, a hypercoagulative status, which seems to be higher when a tourniquet is not used, has been reported [1]. The low incidence of DVT in our study may be due to prophylaxis with enoxaparine, where we followed the international consensus statement regarding prevention of venous thromboembolism [8, 16].

Acknowledgements The authors thank Rémy Nizard, M.D., Ph.D., for the statistical analysis

References

1. Aglietti P, Baldini A, Vena LM, Abbate R, Fedi S, Falciani M (2000) Effect of tourniquet use on activation of coagulation in total knee replacement. Clin Orthop: 169–177
2. Barwell J, Anderson G, Hassan A, Rawlings I, Barwell NJ (1997) The effects of early tourniquet release during total knee arthroplasty: a prospective randomized double-blind study. J Bone Joint Surg [Br] 79: 265–268
3. Berman AT, Geissele AE, Bosacco SJ (1988) Blood loss with total knee arthroplasty. Clin Orthop 234: 137–138
4. Burkart BC, Bourne RB, Rorabeck CH, Kirk PG, Nott L (1994) The efficacy of tourniquet release in blood conservation after total knee arthroplasty. Clin Orthop: 299: 147–152
5. Cushner FD, Friedman RJ (1991) Blood loss in total knee arthroplasty. Clin Orthop: 269: 98–101
6. Gross JB (1983) Estimating allowable blood loss: corrected for dilution. Anesthesiology 58: 277–280.
7. Harvey EJ, Leclerc J, Brooks CE, Burke DL (1997) Effect of tourniquet use on blood loss and incidence of deep vein thrombosis in total knee arthroplasty. J Arthroplasty 12: 291–296
8. International consensus statement (guidelines according to scientific evidence) (1997). Prevention of venous thromboembolism. Int Angiol 16: 3–38
9. Jarolem KL, Scott DF, Jaffe WL, Stein KS, Jaffe FF, Atik T (1995) A comparison of blood loss and transfusion requirements in total knee arthroplasty with and without arterial tourniquet. Am J Orthop 24: 906–909
10. Jorn LP, Lindstrand A, Toksvig-Larsen S. (1999) Tourniquet release for hemostasis increases bleeding. A randomized study of 77 knee replacements. Acta Orthop Scand 70: 265–267
11. Lotke PA, Faralli VJ, Orenstein EM, Ecker ML (1991) Blood loss after total knee replacement. Effects of tourniquet release and continuous passive motion. J Bone Joint Surg [Am] 73: 1037–1040
12. Mylod AG Jr, France MP, Muser DE, Parsons JR (1990) Perioperative blood loss associated with total knee arthroplasty. A comparison of procedures performed with and without cementing. J Bone Joint Surg [Am] 72: 1010–1012
13. Newman RJ (1984) Metabolic effects of tourniquet ischaemia studied by nuclear magnetic resonance spectroscopy. J Bone Joint Surg [Br] 66: 434–440
14. Salam A, Eyres KS (1995) Effects of tourniquet during total knee arthroplasty. A prospective randomised study. J Bone Joint Surg [Br] 77: 250–253
15. Stringer MD, Steadman CA, Hedges AR, Thomas EM, Morley TR, Kakkar VV (1989) Deep vein thrombosis after elective knee surgery. An incidence study in 312 patients. J Bone Joint Surg [Br] 71: 492–497
16. Thromboembolic risk factors (THRIFT) consensus group (1992) Risk of and prophylaxis for venous thromboembolism in hospital patients. BMJ 305: 567–574
17. Wakankar HM, Nicholl JE, Koka R, D'Arcy JC (1999) The tourniquet in total knee arthroplasty. A prospective, randomised study. J Bone Joint Surg [Br] 81: 30–33
18. Worland RL, Arredondo J, Angles F, Lopez-Jimenez F, Jessup DE (1997) Thigh pain following tourniquet application in simultaneous bilateral total knee replacement arthroplasty. J Arthroplasty 12: 848–852